Donaldson (H. H.) & Bolton (T. L.)

THE SIZE OF SEVERAL CRANIAL NERVES IN MAN AS INDICATED BY THE AREAS OF THEIR CROSS-SECTIONS.

HENRY H. DONALDSON AND T. L. BOLTON.
FROM THE NEUROLOGICAL LABORATORY OF CLARK UNIVERSITY, WORCESTER, MASS.

Reprinted from The American Journal of Psychology, Vol. IV, No. 2, Dec., 1891; pp. 224–229.

LIBRARY
AUG 2
666.

With the compliments of

Henry H. Donaldson.

THE SIZE OF SEVERAL CRANIAL NERVES IN MAN AS INDICATED BY THE AREAS OF THEIR CROSS-SECTIONS.

HENRY H. DONALDSON AND T. L. BOLTON.

(From the Neurological Laboratory of Clark University.)

Reprinted from The American Journal of Psychology, Vol. IV, No. 2.

On several of the cranial nerves of man we have measured the areas of cross-sections, taken at definite points, and sought by this means to get a numerical expression for the size of these nerves. The immediate reason for the investigation was the desire to compare with normal material the cranial nerves of the blind deaf-mute Laura Bridgman in order to determine in her case how far these nerves departed from the normal size. The relation of the size of the cranial nerves to the other structures with which they are associated is a matter of much interest, but one to which, at the moment, we have nothing to contribute.

Little importance seems to have been attached to the size of these nerves by those authors whom we have been able to consult. In general the text books have nothing to say on the subject. Schwalbe (1), v. Gudden (2), Salzer (3) and W. Krause (4) have measured the area of the cross-section of the optic nerve in man, for the most part near the bulb, and have obtained areas as small as 7.09 sq. mm. Obersteiner(5) gives the average area as about 9 sq. mm. Since, however, our sections and theirs were not made at similar points on the nerve, a detailed comparison is unnecessary. In addition to the Bridgman specimen the material employed consisted of seven male and three female encephala. A few brief statements will be necessary by way of comment upon the Table I. in which we embody our results.

Only the first, second, third and fourth nerves have been studied. The olfactory bulb was sectioned where it was thickest. The olfactory tract where it was thinnest. The optic nerves about 10 mm. from the chiasma. The oculomotor nerves about 10 mm. from their superficial origin and the trochleares at the point where they lie on the lateral aspect of the brain stem.

In forming the table the distinction between the nerves of the right and those of the left side is neglected, but the

LIBRARY
SURGEON GENERAL'S OFFICE
AUG 24 1900
666,

number for the larger nerve always stand first in order. To the above statement the nerves from the Bridgman brain form an exception, as in that case right and left are distinguished.

The cases have been divided according to sex and ranged in each group according to encephalic weight, with a view to bringing out any relation which might exist between sex or brain-weight and the size of the nerves. Where the two nerves of a pair have been measured there is often a large difference amounting in some cases to 25 %, as indicated in the column showing differences, expressed in percentage of the smaller member of the pair. When similar nerves from different brains are compared the differences are often much greater than between the members of the same pair. This difference in individuals corresponds with the results obtained by counting the nerve fibres in the cranial nerves—Krause([6]). Microscopical examination of the sections showed that the differences in area between the normal individuals was only to a small degree dependent on differences in the amount of connective tissue.

We conclude therefore that, while our table is too small to permit any inference concerning the relation of sex or encephalic weight to the size of the cranial nerves, we may infer some asymmetry in nerves of the same brain and a very great difference in the size of the cranial nerves in different normal individuals. When the nerves of the Bridgman brain are compared with the normals both the olfactory bulb and the tract are found to be small, but neither one is so small as in some of the normals. The optic nerves are both much smaller than any of the normals, and differ from one another in a way which will be discussed elsewhere, while the oculomotor nerves are large.

Methods Employed.

The value of the results just given depends, of course, on the reliability of the methods which were used to obtain them. It has seemed to us best to give an account of these, together with the sources of error, under a separate heading, since it could be done in this way more concisely.

It is desirable that we should be able to measure the area of a given cross-section within $\pm$ 5%, and that the cross-section which is measured should represent that of the fresh nerve, and be neither swollen nor shrunken by the treatment which it has received.

We shall first consider the method of measuring. Not having a planimeter, we adopted the method employed by v. Gudden ([2]). The mounted section was projected upon a

TABLE I.

GIVING AREAS OF THE CROSS-SECTIONS OF SEVERAL CRANIAL NERVES, NATURAL SIZE. THE UNIT OF MEASURE BEING 1 SQUARE mm.
THE NERVES ARE DESIGNATED BY THEIR SERIAL NUMBER.

Catalog Number.	Nationality.	Age.	Sex.	Weight of Encephalon with Pia in Grammes.	Cause of Death.	Autopsy, hours after Death.	Nerve I. Bulb.	Nerve I. Bulb.	Differ by	Nerve I. Tract.	Nerve I. Tract.	Differ by	Nerve II.	Nerve II.	Differ by	Nerve III.	Nerve III.	Differ by	Nerve IV.	Nerve IV.	Differ by	Remarks.
15	American.	20	Male.	1520	. . . . . .	24	8.88	. . .	. . .	2.24	. . .	. . .	12.15	12.07	0.6%	5.59	4.61	12%	0.292	. . .	. . .	. . . .
9	. . . . .	57	"	1464	. . . . . .	30	5.78	5.46	5%	1.62	1.53	5%	9.92	9.07	9%	. . . .	. . . .	. . .	. . .	. . .	. . .	. . . .
10	. . . . .	35	"	1443	Diffuse Nephritis.	22	9.50	. . .	. . .	2.37	2.32	2%	13.35	12.93	2%	2.74	2.71	1%	0.294	0.285	3%	. . . .
13	Negro, American.	60	"	1432	. . . . . .	20	9.23	. . .	. . .	4.23	3.77	12%	17.37	13.98	24%	2.04	2.04	0.4%	0.286	. . .	. . .	. . . .
12	. . . . .	35	"	1419	. . . . . .	28	7.75	. . .	. . .	3.17	3.12	2%	12.78	12.41	2%	2.94	2.82	4%	0.358	0.329	8%	. . . .
3	Irish.	39	"	1393	Tuberculosis.	10	. . . .	. . .	. . .	1.84	1.82	1%	12.07	11.67	3%	2.74	2.70	1%	0.778	. . .	. . .	. . . .
2	. . . . .	45	"	1367	Aneurism of Aorta.	18	9.09	. . .	. . .	2.86	. . .	. . .	16.32	13.03	25%	2.12	. . . .	. . .	. . .	. . .	. . .	. . . .
11	. . . . .	40	Female.	1196	Phthisis.	10	. . . .	. . .	. . .	1.06	1.05	0.3%	10.00	8.74	14%	. . . .	2.27	. . .	. . .	. . .	. . .	. . . .
1	Belgian.	45	"	1173	Intestinal Abcess.	18	7.65	. . .	. . .	2.59	2.57	1%	10.85	10.39	4%	3.40	3.23	4%	0.492	0.467	5%	. . . .
14	. . . . .	65	"	1040	. . . . . .	30	8.48	6.92	22%	2.03	1.82	11%	11.61	11.17	3%	2.13	2.13	0%	0.209	. . .	. . .	General Atrophy of Encephalon.
L. B.	American.	60	"	1204	Lobar Pneumonia.	8	(r)6.34	. . .	. . .	(r)1.46	. . .	. . .	(r) 5.00	(l) 3.38	47%	(r)3.17	(l)3.51	10%	. . .	. . .	. . .	. . . .

vertical glass plate upon which tracing paper was fastened. The outline of the picture on the tracing paper was then followed with a hard pencil; the outline in all cases being taken inside of the epineurium. The amount of enlargement was usually 25 diameters; for the smallest nerves, in some cases, about double this enlargement was used. The amount of enlargement was determined by projecting a surface ruled in squares 0.5 mm. on each side. This surface had been previously tested and the ruling found to be accurate. The parts of the projecting apparatus were rigidly fixed and the enlargement tested both before and after each set of observations. The error here depends on the accuracy with which the outline can be followed with the pencil, and amounts at most to 1 or 2 per cent. To balance this error two tracings were made from each section. The tracings were next transferred to tin foil by laying the paper over the foil and following the outline on the paper with a fine but blunt metal point, thus impressing it on the foil. The piece of foil was then cut out and weighed. Its weight divided by the weight of 1 sq. cm. of foil gave the number of square centimeters contained in it and this in turn divided by the square of the number of diameters by which it had been enlarged, gave the area of the section in its original size. If for the moment we consider the tin foil to have a uniform thickness, then the first source of error is that of impressing the outline traced on the paper, upon the foil. Next is the error due to cutting out the piece of foil. The cutting was done with a small, thin and pointed scalpel. The errors here are small and may be considered as less than 1 per cent. To balance them as far as possible each outline on the paper was twice impressed on the foil. Since each section had been twice outlined and each of these outlines twice impressed on the foil, there were finally four pieces of foil representing each section. These at first were weighed separately, to give us a notion of the amount of variation, but later in the investigation they were weighed all together, and the average taken. The weighing was done upon chemical balances weighing to tenths of mgr., and no error of importance entered these. The further reduction was simply a matter of arithmetic.

To return to the foil which is an all important factor. That used consisted of a continuous roll one foot wide. To obtain samples from this an accurately made square brass frame, enclosing an area 3 cm. on each side, was laid on the foil and the enclosed area of foil cut out with the scalpel. The weight of one sq. cm., obtained by calculation from the weight of pieces containing 9 sq cm., was found to range between .0619 + and 0674 + grms. The average of 54 samples of the

foil showed the weight of 1 sq. cm. equal to .648 grms., which is very nearly the mean of the extremes just given. Careful testing showed that the two inches of foil on each edge of the roll gave the minimum weight, so that the greatest variation was in a line from side to side, across the roll. The difference in the extreme weight amounts to about 9% of the smaller figure—.0619 grms. This gives the impression of rather more irregularity in the foil than really occurred. If we take the 54 samples we find that 40% of them are within $\pm$ 1% of the average and that 80% are within $\pm$ 2% of the average. Since the pieces used as samples were taken, as a rule, closer to the foil representing the nerve than they were to one another and in many cases the sample was taken from within the foil representing the nerve, the amount of error introduced by the variations in the weight of the foil can be calculated as within 2%. It will thus be seen that the cumulative errors due to outlining, cutting and variations in foil might amount to 5% but the probability of their doing so in any single instance was small.

In carrying out these measurements the usual rules employed in psycho-physical work to avoid prejudicing the results were followed. The results therefore are naïve and such coincidences as occur are entirely unforced. If we knew that the section as prepared on the slide had the same area as in the natural state we might end our discussion here. Since, however, the area has been influenced by the treatment of the specimen we are compelled to give our methods in detail and estimate, as best we can, the amount of correction required.

The fresh nerves were all placed in a solution of $2\frac{1}{2}$% bichromate of potash plus $\frac{1}{6}$ its volume of 95% alcohol. In this they remained for three weeks. They were then washed for a day in water, put in 95% alcohol for 3 or 4 days and finally in 80% alcohol in which they were kept until imbedded. We have determined that the reaction to reagents of the nerve-tissues of the sheep is similar to that of man. To test then, in detail, the influence of this treatment we took similar nerves from the sheep and subjected them to like conditions. For this purpose six olfactory bulbs, six olfactory tracts, and three pairs of optic nerves from the sheep were weighed and the volume taken and then carried through the several solutions.

Thus they were prepared as the human nerves had been. Finally in 80% alcohol the volume for the olfactory bulbs was found to be 5.2% greater than in the fresh specimen, that for the olfactory tracts 8.8% greater, and that for the optics 2.6% greater. So far as we have observed the variation in volume is symmetrical for the olfactory bulbs and racts but for the optic nerves it is not symmetrical.

In the first two instances the square of the cube root of the total enlargement will give as the area desired.

Hence for olfactory bulb,	area = 101.7%
" " tract,	" = 102.0%
" *optic nerves,	" = 105.8%

That is, the areas of the bulb, tract and optic nerves are respectively 1.7%, 2% and 5.8% more than in the nerve in its natural state. The original observations are therefore to be corrected for this increase.

Specimens were imbedded in celloidin in the usual manner. By cutting a section before imbedding, then carrying the specimen through the process and cutting another section, it was found that imbedding in celloidin did not influence the area of the section. The sections were treated as follows: stained in a solution of acid fuchsin (acid fuchsin 1 grm., 95% alcohol 80 c.c., aqua. dist. 80 c.c.) for 2 or 3 minutes, washed in water, dehydrated in 95% alcohol, and then cleared either in oleum origanum cretici or Weigert's mixture —3 parts of Xylol plus 1 part of anhydrous carbolic acid— and mounted in Xylol Balsam. Following the sections step by step through this process by taking the outline after applying each reagent, it was found that the treatment produced no change in the area. Other sections from the same specimens were stained for 5 minutes with Delafield's hæmatoxylin diluted to one-third its strength, and then dehydrated and mounted in the manner above described. After the hæmatoxylin, stain, treatment with the Xylol-carbolic clearing solution caused a well-marked swelling of the section and so an increase of area. Sections thus treated were not used for measurement and we only mention this reaction as perhaps of interest in showing the inter-dependence of the various reagents used because when the hæmatoxylin was cleared by oil of origanum the area of the section remained unchanged.

From this it was plain that in order to reduce the sections to natural size they needed to be corrected only for the swelling which had taken place in hardening the specimens. For this correction the numbers above given were used.

The only exception to this general statement was in the case of the optic nerves of Laura Bridgman which were so poor in medullary substance that it seemed fair to suppose that they would swell but very slightly, if at all, in the process of hardening and therefore the numbers which appear in the table represent the actual size of the hardened sections. The

---

*The method of obtaining the figure for the optic nerve will be ex plained in another paper.

other nerves, III and IV, in Table I, were corrected as though like the optic nerve in reaction.

It need only be added that the microtome used for making the sections permitted us to adjust the position of the object so that the sections could be cut at right angles to the axes of the nerves. Care was taken to that this was done with all possible accuracy.

A source of error exists in the determination of the part of the olfactory bulb which is thickest and the part of the tract which is thinnest, but since the pairs of sections from the same brain coincide fairly well it does not seem to us that our results are seriously affected by this disturbing factor.

We conclude therefore :

1. That the symmetrical nerves in normal brains tend to be alike.
2. That there may be great differences between individuals in the size of these nerves.
3. That the figures in the table represent within $\pm 5\%$ the areasof the several nerves reduced to their natural size.

In Laura Bridgman.

4. That the olfactory bulbs and tracts are small.
5. That the optic nerves—especially the left optic,—are very small.
6. That the 3rd nerves are normal in size.

Bibliography.

Reference. Nos.	Date.	Title.
1.	1887.	Schwalbe. Lehrbuch der Anatomie der Sinnesorgane. Erlangen, vide p. 85.
2	1889.	v. Gudden. Gesammelte und hinterlassene Abhandlungen. Wiesbaden, vide p. 161.
3.	1880.	Salzer. Ueber die Anzahl der Sehnervenfasern und der Retinazapfen im Auge des Menschen. Sitzungsber. d. Wien. Akad. d. Wissen. Wien. Bd. 81. Abthl. III.
4.	1880.	Krause, W. Ueber die Fasern des Sehnerven. Arch.f. Opthalmologie Bd. 26 p. 102.
5.	1887.	Obersteiner, H. Anleitung beim Studium der Bau des Nervösencentralorgane im gesunden u. kranken Zustande. Wien, 1887.
6.	1876.	Krause, W. Handbuch der menschlichen Anatomie. Hannover. Bd. 1. vide p. 472. The numbers there given are based mainly on Rosenthal's "Diss. de num. atque mens. micr. fibrill. Vratisl. 1845." This paper we have been unable to see.

How look up real estate